

Los Alamos National Laboratory
Environmental Restoration Program
Standard Operating Procedure

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Well Slug Tests

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WELL SLUG TEST

1.0 PURPOSE

This procedure defines field methods for the collection of data for determining saturated hydraulic conductivity under in situ conditions by the slug test withdrawal method of analysis for the Environmental Restoration (ER) program.

2.0 SCOPE

2.1 Applicability

This procedure is applicable for determining hydraulic conductivity using the slug test withdrawal method for the ER program.

2.2 Training

The field team leader is responsible for monitoring the proper implementation of this procedure. The field team members should be familiar with the objectives of slug testing and should document that they have both read and understand this procedure and the procedures in Section 1.0, General Instructions.

3.0 DEFINITIONS

- A. Hydraulic conductivity: The flow rate of water in gallons per day through a cross section of one square foot under a unit hydraulic gradient, at the prevailing temperature (gpd/ft²).
- B. Storage coefficient(s): The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head.

4.0 BACKGROUND AND/OR CAUTIONS

The slug test measures the rate at which groundwater stabilizes in a well over time due to the injection or withdrawal of a mass (slug) beneath the groundwater surface. From this water level fluctuation versus time data, the hydraulic conductivity of the immediate area can be determined. Refer to the site-specific work plan for more information on the scope of work activities for which slug testing is required and the locations of the wells that are to be tested.

With the slug test the hydraulic conductivity or transmissibility of an aquifer is determined from the rate of rise of the water level in a well or borehole after a certain volume or "slug" of water is suddenly removed from the well. The slug is inserted and the water level is allowed to reach equilibrium. Then the slug is suddenly removed and the rise in water level is measured with time.

The primary advantages of using slug tests to estimate conductivities are: (a) estimates can be made in situ and errors incurred in the laboratory testing of disturbed samples can be avoided; (b) tests can be performed quickly at relatively low costs because a pumping well and observation wells are not required; and (c) the hydraulic conductivity of small, discrete portions of an aquifer can be estimated (for example, sand layers in a clay).

Limitations of slug testing include: (a) only the hydraulic conductivity of the area immediately surrounding the well is estimated, which may not be representative of the average hydraulic conductivity of the local area; (b) certain assumptions made in the analysis process; if the assumptions are inappropriate for the geologic conditions at the site, the slug test data are invalid; (c) the storage coefficient, S , usually cannot be determined; and (d) data sufficient for analysis may not be collected if the hydraulic conductivity is relatively high.

The time required for a slug test is a function of the volume of the slug, the hydraulic conductivity of the formation, and the type of well completion. The slug volume should be large enough that a sufficient number of water level measurements can be made before the water level returns to equilibrium conditions. The length of the test may range from less than a minute to several hours.

If the well is to be used as a monitoring well, take precautions so that the contamination does not occur through material introduced into the well. If water is added to the monitoring well, obtain it from an uncontaminated source and transport it in a clean container. Clean bailers or measuring devices before the test (SOP-02.07, General Equipment Decontamination). If tests are performed on more than one monitoring well, avoid cross-contamination of the wells.

Conduct slug tests on relatively undisturbed wells. If a test is conducted on a well that has recently been pumped for water-sampling purposes, the measured water level must be within 0.1 ft of the water level before sampling. At least one week should elapse between the drilling of a well and the performance of a slug test.

NOTE: The exact dimensions of the monitoring well, borehole, casing, and sand pack must be recorded to analyze the slug test data correctly.

Site workers preparing for field operations should read and understand the procedures outlined in LANL-ER-SOPs, Section 2.0, Health and Safety in the Field. In addition, site workers should refer to site-specific Operable Unit Health and Safety plans for the particular health and safety equipment to be used.

5.0 EQUIPMENT

Equipment to implement this procedure is listed in Attachment A.

6.0 PROCEDURE

The following general procedures should be used to collect and report slug test data. The procedures required for a particular slug test may vary slightly from those described, depending on site-specific conditions. Modifications to the test procedures will be contained in the site-specific work plan.

Procedures for conducting the slug test with a pressure transducer and data logger, as well as a water level probe, are described below. Be sure to complete all data collection forms.

6.1 Slug Test with Pressure Transducer and Data Logger

Before beginning the slug test, enter the required information into the electronic data logger. Information may vary, depending on the model used. When using different models, consult the operations manual for the proper data-entry sequence to be used. See SOP-07.01 for the procedure for calibration and use of a pressure transducer.

When the slug test is performed with an electronic data logger and pressure transducer, store all data internally or on computer diskettes or tape. The information will be transferred directly to the main computer and analyzed. Maintain a computer printout of the data in the files as documentation.

- A. Determine the static water level in the well, measuring the depth-to-water periodically for several minutes to several hours, and taking the average of the readings (SOP-07.02, Fluid Level Measurement). Record information on the Groundwater Elevation form found in SOP-07.02. Additional information should be recorded on the Daily Activity log in SOP-01.01.01, Records.
- B. Install the transducer and cable in the well below the target drawdown estimated for the test. Be sure this depth of submergence is within the design range stamped on the transducer. Temporarily tape the transducer cable to the well to keep the transducer at a constant depth.
- C. After connecting the transducer cable to the electronic data logger, enter the initial water level and transducer design range into the recording device according to the manufacturer's instructions. The transducer design range will be stamped on the side of the transducer. Record the initial water level on the recording device.
- D. Smoothly lower the slug or bailer into the well. Where the slug contacts the water can be detected by observing the transducer readout.
- E. Allow the water level to restabilize (within 0.1 ft) and remove the cylinder or bailer. Remove the volumes as quickly and smoothly as possible, because the analysis assumes that an instantaneous change in volume is created in the well.

- F. Continue measuring and recording depth-time measurements until the water level returns to equilibrium conditions or a sufficient number of readings have been made to clearly show a trend on a plot recovery versus the logarithm of time.
- G. Lower the slug and repeat the data collection portions of step F.

6.2 Slug Test with Water Level Probe

If the slug test data are collected and recorded manually, record observations on the Slug Test Data form (Attachment B). Fill out the form as described in Attachment C. This method should only be used if an electronic data recorder cannot be obtained. This method cannot be used for aquifers with a high hydraulic conductivity because stabilization of groundwater will occur rapidly.

- A. Determine the static water level in the well, measuring the depth-to-water periodically for several minutes and taking the average of the readings (SOP-07.02). Record results on the Groundwater Elevation form.

NOTE: When measuring water level changes, it is important to take the measurements rapidly for accurate results.

- B. Smoothly lower the slug or bailer into the well. Where the top slug contacts the water can be estimated by marking the depth-to-water found in part A onto the slug line.
- C. Measure and record the depth-to-water and the time at each reading. The moment when the volume is removed is Time Zero. Depths should be measured to the nearest 0.1 ft. The number of depth-time measurements necessary to complete the test varies.
- D. Continue measuring and recording depth-time measurements until the water level returns to equilibrium conditions or a sufficient number of readings have been made to clearly show a trend on a plot recovery versus the logarithm of time.
- E. Lower the slug and repeat the data collection portions of steps C and D.
- F. Decontaminate the downhole equipment according to SOP-02.07, General Equipment Decontamination. Cut off contaminated portions of rope and dispose of them in accordance with SOP-01.06, Management of RFI-Generated Waste.
- G. If using an electronic data logger, follow the steps listed below.
 - 1. Stop the logging sequence.
 - 2. Print the data or send to the computer by telephone.

3. Save memory and disconnect the battery at the end of the day's activities.

H. Check all data collection forms for completeness.

7.0 REFERENCES

The following procedures are directly associated with this procedure and should be reviewed before slug testing:

LANL-ER-SOPs in Section 1.0, General Instructions.

LANL-ER-SOPs in Section 2.0, Health and Safety in the Field.

LANL-ER-SOP-07.01, Pressure Transducers.

LANL-ER-SOP-07.02, Fluid Level Measurement.

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8.0 RECORDS

- A. A Completed Slug Test Data Form.
- B. A Completed Groundwater Elevation Form.
- C. Daily Activity Log containing any deviations, calibration data, and additional comments.

9.0 ATTACHMENTS

- A. Equipment and Supplies Checklist
- B. Slug Test Data Form
- C. Data Form Completion

EQUIPMENT AND SUPPLIES CHECKLIST FOR WELL SLUG TESTS

- _____ Water pressure transducers, if appropriate
- _____ Electric water level indicator or electronic data logger (if transducer method is used)
- _____ Weighted tapes with plover
- _____ Steel tape (subdivided into hundredths of feet) and blue surveyor's chalk
- _____ Stainless steel slug of a known volume
- _____ Teflon™ or stainless bailer of a known volume
- _____ Watch or stopwatch with second hand
- _____ Tape measure (subdivided into tens of feet)
- _____ Semilog graph paper (if required) and straight edge
- _____ Appropriate references and calculator
- _____ Duct tape
- _____ Nonwater-soluble black ink pens
- _____ Daily Activity Logs
- _____ Groundwater Elevation forms
- _____ Slug Test Data forms

SLUG TEST DATA FORM

[illegible]

DATA FORM COMPLETION

SLUG TEST DATA FORM (ATTACHMENT B)

Use an indelible dark ink pen. Make an entry in each blank. For entry blanks for which no data are obtained, enter UNK for Unknown, NA for Not Applicable, or ND for Not Done. To change an entry, draw a single line through it, add the correct information above it, and date and initial the change. For all forms, complete the following information:

1. Technical Area (TA). Two-digit number indicating the TA in which the sampling is being done or sample is being studied.
2. Operable Unit. Four-digit number indicating the Operable Unit in which the sampling is being done or sample is being studied.
3. Log Date and Time. The date and time when the measurement was made, in the following formats: DD-MMM-YY (e.g., 01-JAN-88), and the 24-hour clock time (e.g., 0837 for 8:37 a.m. and 1912 for 7:12 p.m.).
4. Sheet Number. Number all the sheets that are used for this activity, by day or by some practical unit.
5. Weather and Other Comments. Record all other conditions pertinent to the sample collection in this section on the Daily Activity Log in SOP-01.04.
6. Test Method. The slug device is withdrawn (pulled out) from the monitor well.
7. Elapsed Time (Min). Cumulative time readings from the beginning of the test to the end of the test in minutes.
8. Depth-to-Water (Ft). Depth of water recorded in hundredths of feet.
9. Method of Water Level Measurement. Record the type of instrument used to measure water level.
10. Exact Slug Dimensions. The slug and/or bailer dimensions must be known in order to perform calculations properly.
11. Well Construction Details. The well screen length, sand pack length, cased intervals, and borehole dimensions must be known, at a minimum, to perform calculations.